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ENVIRONMENTAL MANAGEMENT CORP.

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Please Refer To:
AEMC Job No. 82580

4 January 1991

Mr. Paul Smith
Division of Hazardous Materials
Alameda County Department of Environmental Health
80 Swan Way, Room 200
Oakland, California 94621

RE: PRELIMINARY REPORT AND CONTAMINATION ASSESSMENT WORKPLAN SEARS, ROEBUCK AND CO., OAKLAND, CALIFORNIA

Dear Mr. Smith:

American Environmental Management Corporation (AEMC) is pleased to submit the following document as part of the underground storage tank closure activities at 2633 Telegraph Avenue, Oakland, California.

If you have any questions or comments regarding the progress of the project, please do not hesitate to call Mr. Phil Walsack or me at (916) 364-8872.

Sincerely,

James F. Frumm

REGISTERED GEOLOGIST
JAMES F. FRUMM
No. 4207
STATE OF CALIFORNIA

James F. Frumm, R.G., R.E.A.
Regional Manager
Engineering Division

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11src-01(pw-3)

Enclosure

Job No. 82580

PRELIMINARY REPORT
and
CONTAMINATION ASSESSMENT WORKPLAN

for

SEARS, ROEBUCK and CO.
Oakland, California

4 January 1991

prepared by the

AMERICAN ENVIRONMENTAL MANAGEMENT CORPORATION
Engineering Division
9719 Lincoln Village Drive, Suite 501
Sacramento, California 95827
(916) 364-8872

I hereby certify that this
Preliminary Report and Contamination Assessment Workplan
for
Sears, Roebuck and Co. of Oakland, California
was prepared under my direct supervision.

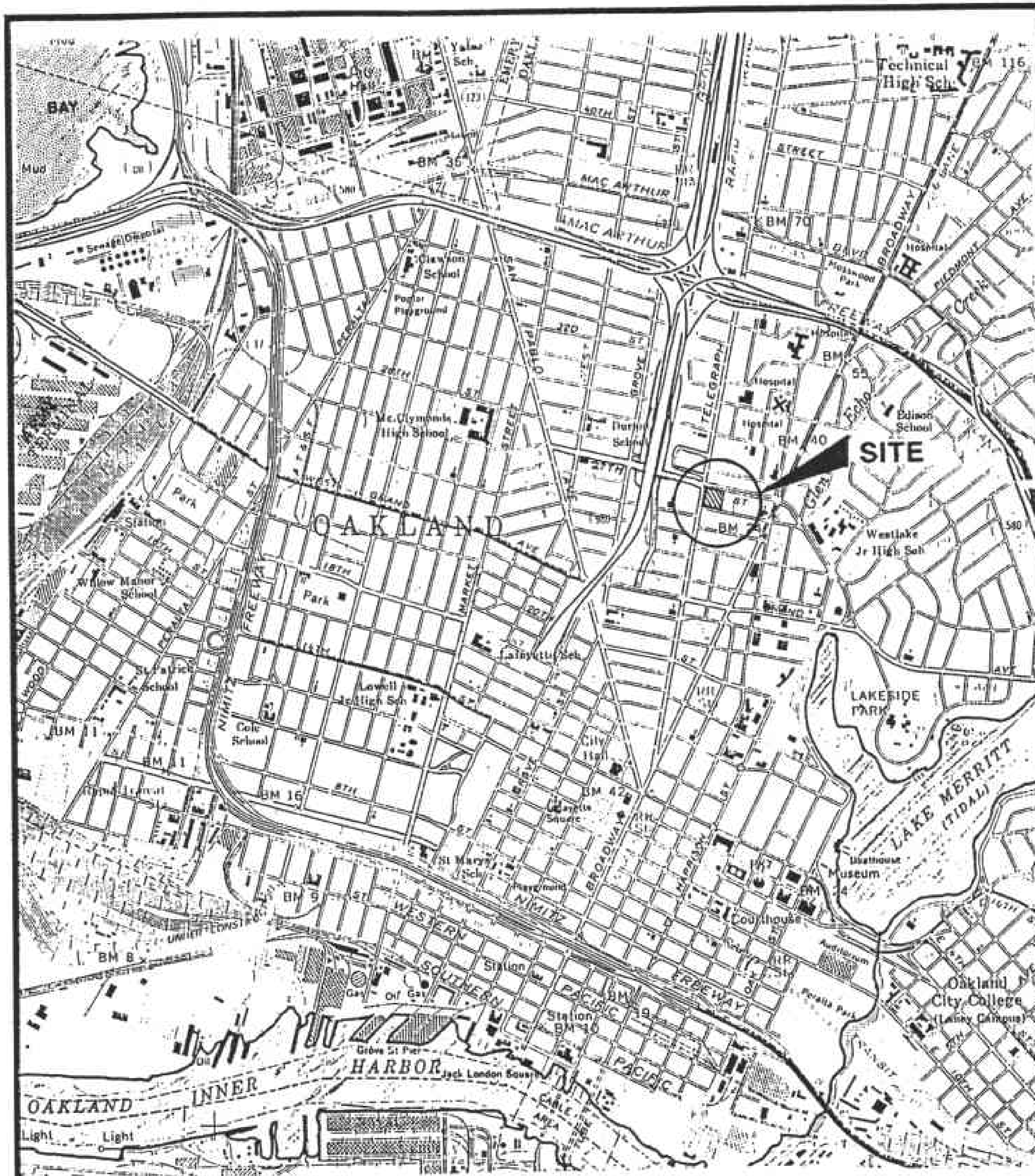
REGISTERED GEOLOGIST
JAMES F. FRUMM
No. 4207
STATE OF CALIFORNIA

James F. Frumm, R.G., R.E.A.
Regional Manager
Engineering Division
American Environmental Management Corporation

INTRODUCTION

American Environmental Management Corporation (AEMC) has been retained by Ms. Bernadine Palka of Sears, Roebuck and Co. (Sears) to submit a Preliminary Report (PR) and Contamination Assessment Workplan regarding the hydrocarbon contamination discovered during the removal of seven (7) underground storage tanks (USTs) at the company's automotive repair facility located at 2633 Telegraph Avenue, Oakland, California (Figure 1).

The purpose of this report is to summarize initial investigative results and to develop a workplan which will assess the vertical and lateral extent of petroleum hydrocarbon contamination at the site.



U.S.G.S.
Oakland West
QUADRANGLE LOCATION
7.5 MIN. SERIES

1000' 0' 1000' 2000'

SCALE: 1"=2000-ft.

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FIGURE 1
SITE LOCATION MAP

SEARS AUTOMOTIVE - Oakland, California

DRAWN BY:	GPM	DATE:	12/3/90	PROJECT NO.	82580

INITIAL SITE INVESTIGATION

Sears has maintained seven (7) underground storage tanks to store oil products for automotive servicing. All of the USTs were installed in the early 1960s and were removed by AEMC during the week of 17 September 1990.

Two separate excavations were opened during the UST removals. Six motor oil tanks were removed from an excavation to the east of the service bays, and one waste oil tank was removed from an excavation to the west of the service bays (Figure 2). Due to the presence of hydrocarbon contamination in both excavations, the site characterization and remediation has been divided into two separate parts, the motor oil tank area and the waste oil tank area. This Preliminary Report and Contamination Assessment Workplan addresses the waste oil tank area.

On 19 September 1990, the 1,000-gallon waste oil tank (Tank 7) was excavated and removed by AEMC. It was noted that the tank had two holes in the bottom of its southern side and many corrosion pinholes. Soil in the excavation was stained. Two soil samples, SB-7A and SB-7B were gathered 9 feet below ground surface (Table 1). AEMC's letter report dated 12 October 1990 summarizes the tank excavation and removal activities.

Approximately 30 cubic yards of excavated soil is presently stockpiled northwest of the site. Two samples, SP-3-1 and SP-3-2, were obtained from the stockpile to characterize the degree of contamination (Table 1). The stockpile is placed on and covered with Visqueen sheeting.

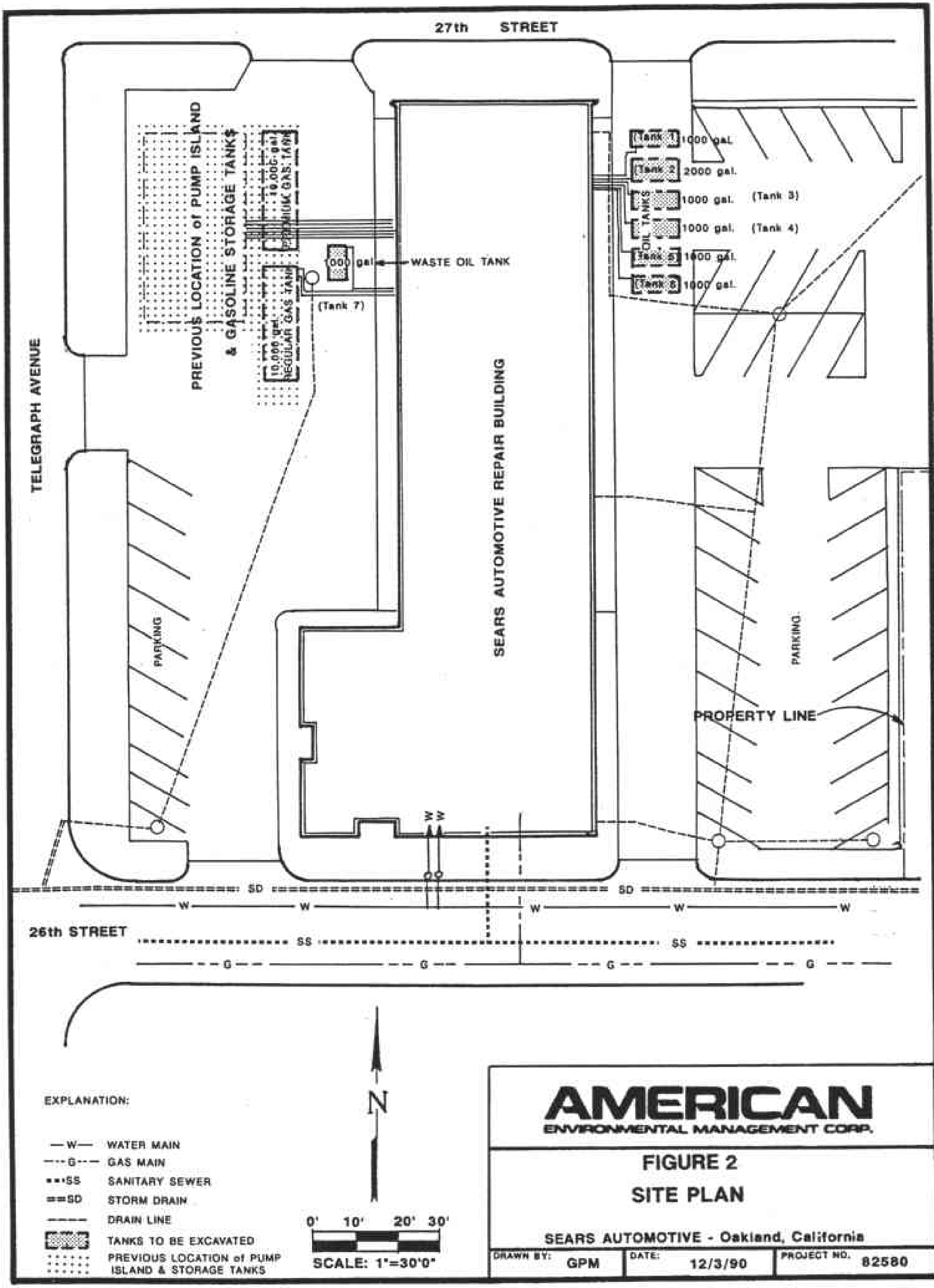

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FIGURE 2
SITE PLAN

SEARS AUTOMOTIVE - Oakland, California

DRAWN BY: GPM	DATE: 12/3/90	PROJECT NO. 82580

TABLE 1

Analytical Results of Soil Samples
Sears, Roebuck and Co.
Oakland, California

Waste Oil Tank Area

Sample ID	Depth (feet bgs)	TPH-G (ppm)	TPH-D (ppm)	Oil & Grease (ppm)	B (ppb)	T (ppb)	E (ppb)	X (ppb)	Cd (ppm)	Cr (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
Excavation													
SB-7A[a]	9	31	2,800	3,200	ND	58	100	720	ND	33	28	360	54
SB-7B[b]	9	31	1,500	2,100	12	200	250	1,400	ND	28	24	190	64
Stockpile													
SP-3-1[c]	—	39	4,400	6,800	ND	310	410	3,000	ND	20	20	440	62
SP-3-2	—	13	850	1,600	ND	9	23	220	1	32	34	47	45

bgs below ground surface

TPH-G Total Petroleum Hydrocarbons as gasoline
TPH-D Total Petroleum Hydrocarbons as diesel
B Benzene
T Toluene
X Xylenes
E Ethylbenzene
Cd Cadmium
Cr Chromium
Ni Nickel
Pb Lead
Zn Zinc

a Sample also contained: Tetrachloroethene @ 82 ppb
Trichloroethene @ 17 ppb

b Sample also contained: Acetone @ 140 ppb
Tetrachloroethene @ 7 ppb
Trichloroethane @ 19 ppb

c Sample also contained: Tetrachloroethene @ 52 ppb

GEOLOGY AND GEOHYDROLOGY

The site, located in the City of Oakland, lies within the San Francisco Bay area of the Coast Range Geomorphic Province. This province is characterized by a series of nearly parallel mountain ranges that trend obliquely to the coast in a northwesterly direction. The alignment of the major fault zones throughout the San Francisco Bay area trend in the same northwesterly direction. The area surrounding the site is bounded by the seismically active Hayward Fault to the east and the San Francisco Bay to the west.

The bedrock underlying most of the East Bay area is composed of sandstone, siltstone, chert and greenstone of the Franciscan Formation and is Jurassic-Cretaceous in age. The Franciscan Formation is overlain by preconsolidated "old bay mud," sand deposits and "young bay mud" of the Cenozoic Age.

AEMC has observed a bay mud layer of unknown thickness beginning approximately 10 feet below grade. Groundwater in the area is believed to be approximately 25 feet below ground surface. At this time, the groundwater flow direction is not known, but tidal action may influence it.

PROPOSED PRELIMINARY INVESTIGATION

The proposed preliminary investigation is divided into four phases:

PHASE I—CONDUCT ELECTRONIC CONE PENETROMETRY SURVEY

AEMC proposes to use electronic cone penetrometry (ECP) as a tool to determine the lateral and vertical extent of soil stratigraphy above the uppermost groundwater beneath the Sears site. ECP is an in-situ method which involves hydraulically advancing a small diameter cone-shaped electronic probe vertically into the soil. Resistance to probe penetration, and changes in pore water pressures with depth are measured electronically. AEMC will use this data to determine changes in soil types and permeabilities with depth. In addition, the ECP will enable AEMC to determine uppermost groundwater elevation, ?? thus establishing the hydraulic gradient. Since this method does not require the use of a drill rig, the collection, containment and disposal of drill cuttings is avoided. The method is well suited to restricted work spaces, like Sears' heavily used parking lot. See Appendix A for additional information regarding the ECP process.

AEMC proposes to complete fifteen (15) ECP soundings, each to the depth of the uppermost water bearing unit. Upon completion of all soundings and sampling, each sounding location will be surveyed to provide a base of reference. Each ECP sounding borehole will be backfilled to grade with injected cement/bentonite grout to grade, in accordance with Alameda County requirements. Figure 3 illustrates the proposed locations for each ECP sounding.

PHASE II—SOIL SAMPLING AND ANALYSES

AEMC proposes to conduct soil sampling adjacent to the completed ECP soundings. The purpose for the sampling effort will be to determine the lateral and vertical extent of hydrocarbon and metals contamination in the soil profile above uppermost groundwater.

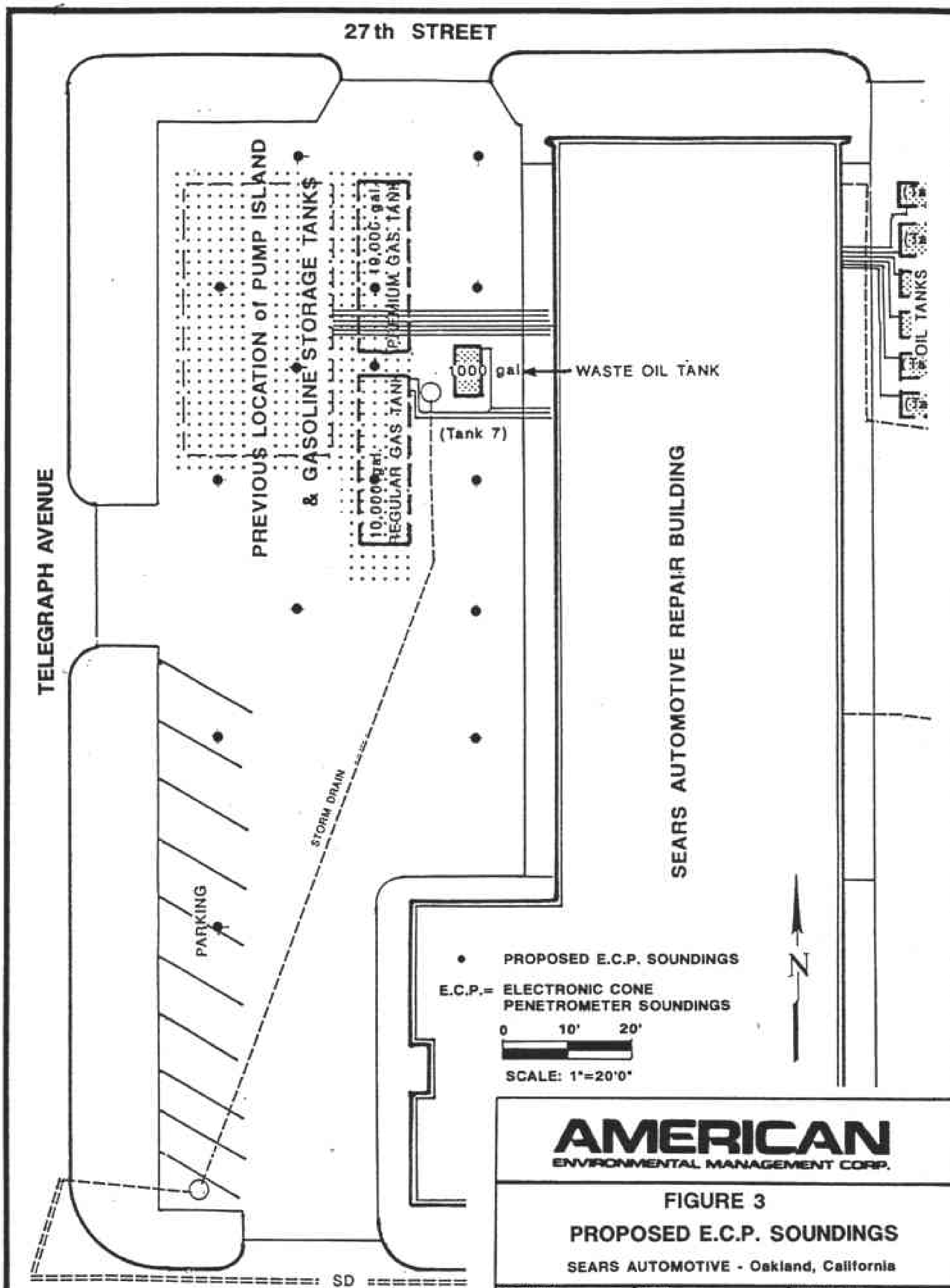

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FIGURE 3

PROPOSED E.C.P. SOUNDINGS

SEARS AUTOMOTIVE - Oakland, California

DRAWN BY: GPM	DATE: 12/3/90	PROJECT NO. 82580

AEMC proposes to advance a total of fifteen (15) soil sampling soundings at the locations illustrated on Figure 4.

AEMC will advance each borehole with the ECP hydraulic press and collect soil samples with the ECP retractable cone tipped sampler as described in Appendix B. Soil samples will be collected every 5 feet downhole beginning at 5 feet below grade to the capillary fringe of the uppermost groundwater.

The soil samples will be analyzed for Total Petroleum Hydrocarbons as Gas and Diesel by EPA Method 8015-m, Oil and Grease by EPA Method 9071, Purgeable Organic Compounds by EPA Method 8240, and Lead by EPA Method ICP/AA (Total Threshold Limit Concentration). All laboratory analyses will be conducted by American Environmental Laboratories Corporation (State Certification No. 210).

AEMC proposes to analyze the soil samples in several stages. The first stage of analysis will consist of soil taken from the five (5) sounding locations closest to the excavation. A second series of analyses will be initiated to further define a zero line of contamination. This process will continue until a zero line is fully defined.

PHASE III—SAMPLE UPPERMOST GROUNDWATER QUALITY

AEMC proposes to sample the uppermost groundwater quality using the ECP with the Hydropunch and BAT sampler as described in Appendix C. AEMC will have confirmed the depth (BGS) of the groundwater by the ECP sounding, thereby establishing the groundwater flow direction. A total of fifteen (15) groundwater quality samples will be obtained, one from each borehole.

The groundwater samples will be analyzed for Total Petroleum Hydrocarbons as Gas and Diesel by EPA Method 8015-m, Oil and Grease by EPA 9071 and Purgeable Organic Compounds by EPA Method 8240.

no metals?

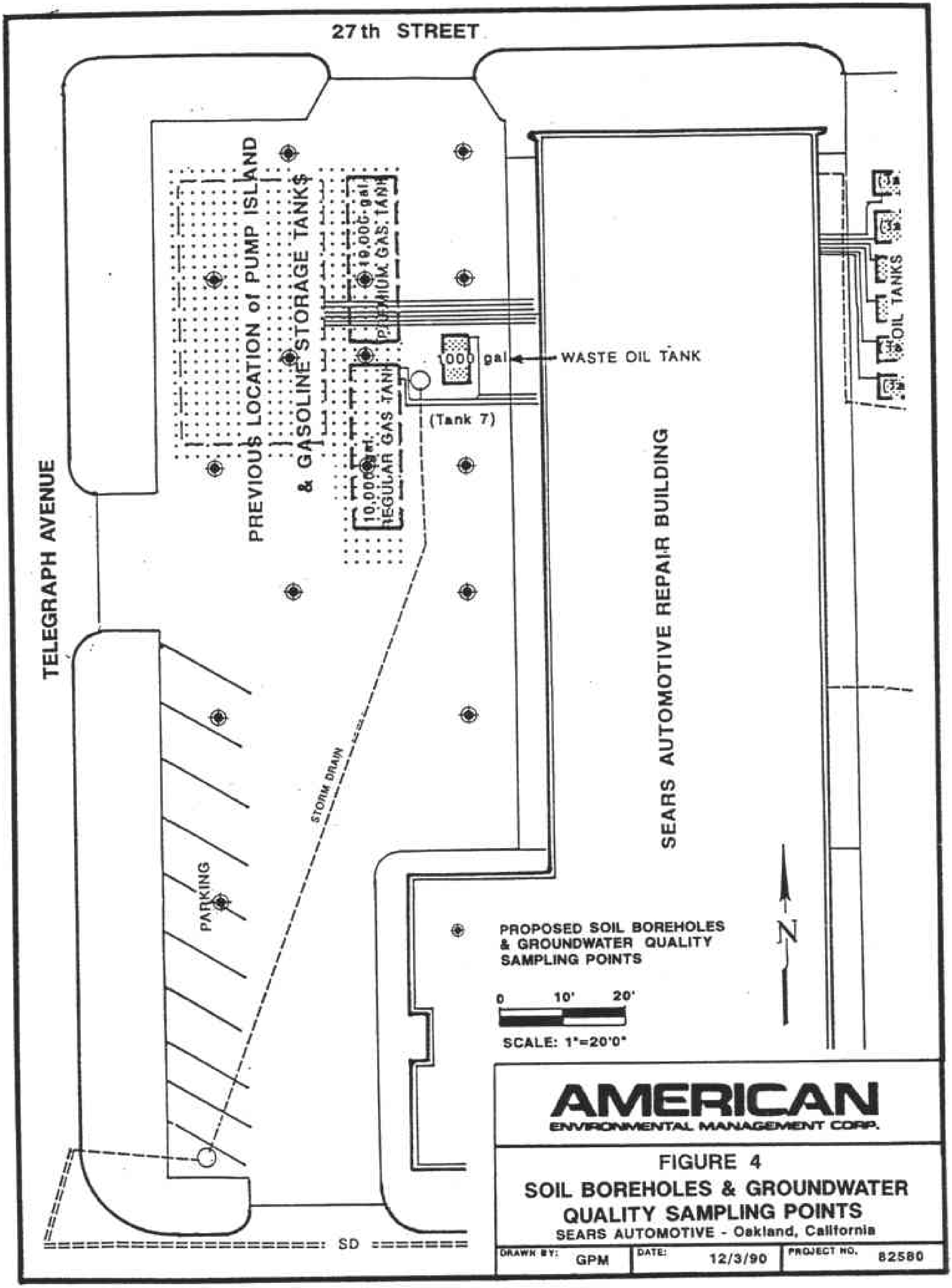


FIGURE 4
SOIL BOREHOLES & GROUNDWATER QUALITY SAMPLING POINTS
SEARS AUTOMOTIVE - Oakland, California

AEMC proposes to analyze the groundwater samples in several stages. The first stage of analysis will consist of groundwater taken from the five (5) boreholes closest to the excavation. A second series of analyses will be initiated to further define a zero line of contamination. This process will continue until a zero line is fully defined.

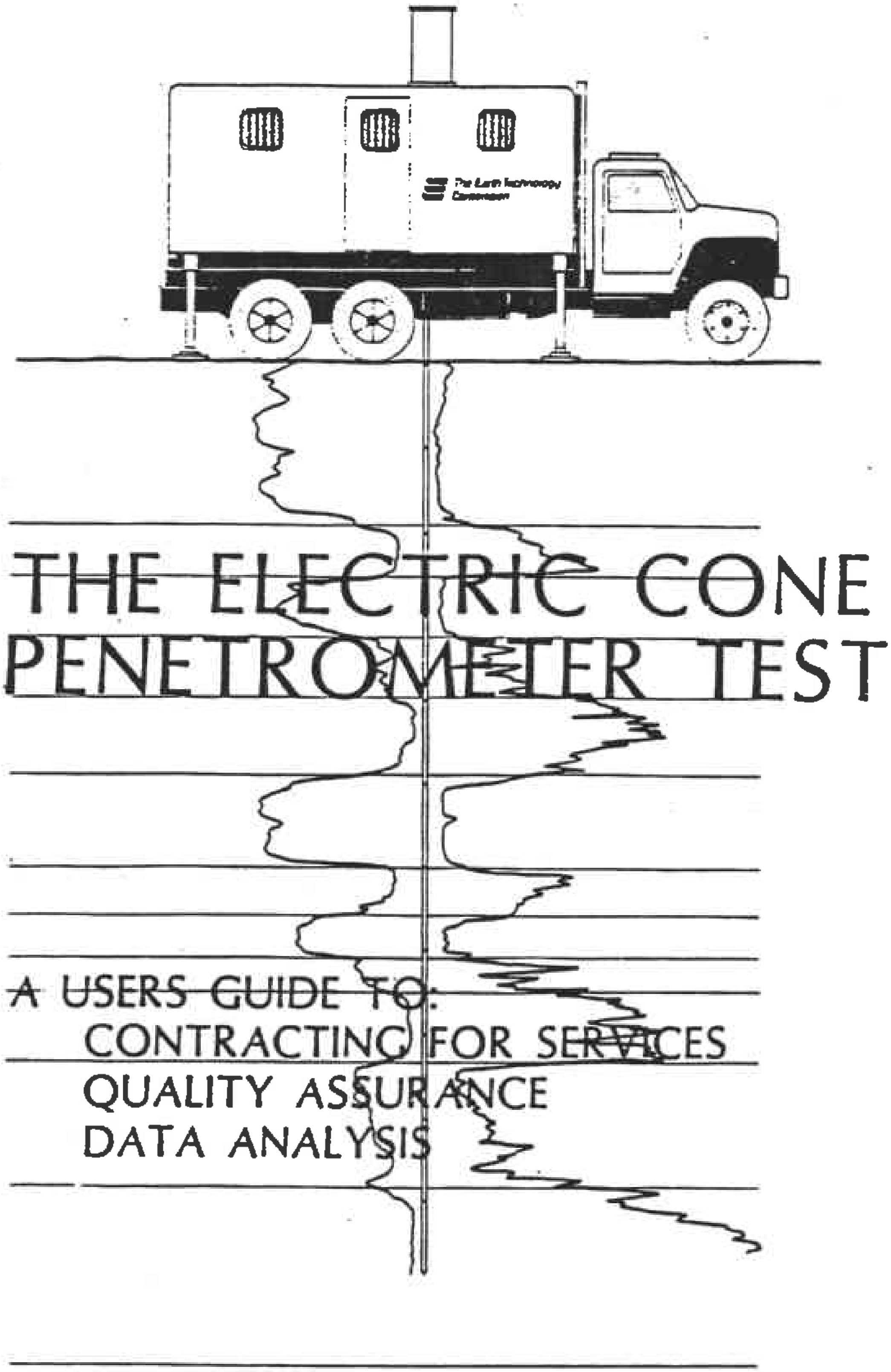
Based on these analytical data, AEMC will determine whether groundwater quality has been affected by hydrocarbon contamination. If all of the groundwater samples are below action levels, AEMC will not install monitoring wells. If groundwater contamination exists, AEMC will be able to place recovery wells and monitoring wells in effective locations based on the ECP soundings and analytical results.

PHASE IV—REPORT PREPARATION

AEMC will prepare a Contamination Assessment Report which will describe the findings of the preliminary investigation. The report will also present recommendations for remedial activities to be conducted.

APPENDIX A

ELECTRIC CONE PENETROMETER



THE ELECTRIC CONE PENETROMETER TEST

A USERS GUIDE TO:
CONTRACTING FOR SERVICES
QUALITY ASSURANCE
DATA ANALYSIS

The Earth Technology
Corporation

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this manual is to provide the practicing geotechnical, civil, or structural engineer with a simple set of summary guidelines related to the use of the electric Cone Penetrometer Test (CPT). The guidelines are intended only as advice to a responsible engineer, and are not intended to replace thorough study of the topic. However, the information contained herein will allow the engineer new to Cone Penetrometer Testing to become familiar with the basic use and pitfalls of the method.

The CPT has been used in European countries for many decades, and so most practicing engineers in those countries are familiar with its standard use and limitations. However, most engineers in the United States have not had such exposure to the method and so have little familiarity with what the CPT is used for, how to use it, when and where to use it and when to expect difficulties in its use.

This manual will present basic recommendations on those topics, including how to contract for services, how to assure data quality, how to interpret and apply the data, and when to require supporting information. The manual closes with a list of recommended references for those needing or desiring additional information.

2.0 WHEN TO USE THE CPT

The CPT is unequaled for delineation of subsurface strata. Whenever site conditions are appropriate, the use of the CPT will benefit a geotechnical exploration project. Essentially all CPT investigations are rapid, provide continuous data, provide repeatable data and utilize automated data logging. Estimates of virtually any soil property can be obtained from CPT data. These factors combine to make the CPT the premier tool for soil stratigraphic logging.

The CPT cannot reliably be used in cobbles, boulders and rock. Further, because there is no historical familiarity with the CPT, most projects require simultaneous conventional borings. Finally, the CPT method cannot provide the material characterization sometimes needed and which can only be obtained by use of other in-situ tests or careful borings, sampling and laboratory testing. The result of these factors is that for very small exploration projects and projects in either very unknown areas or areas known to have critical conditions, careful assessment of the suitability of the CPT should be performed well before project initiation. The potential benefits of the CPT method encourage such assessment on a routine basis.

The ideal use of the CPT is in areas of known geology with soils being gravelly sands or finer. Caliche-rich soils can effectively prevent penetration. A penetration depth of at least 50 feet can be expected when using a full 20 ton CPT system in sites not characterized by extensive coarse grained deposits. Penetration depths in excess of 250 feet have routinely been achieved in fine grained soils.

The questions that need to be answered from the exploration and testing, for example, definition of extent of strata and pile capacity, should be thoroughly defined before any testing is started. In addition, typical soil conditions or properties that separate critical from non-critical conditions should be defined in advance of the first test. In this manner all exploration and testing becomes pertinent to the project needs.

A typical CPT program is laid out and performed to provide the first delineation of overall site subsurface characteristics. Field locations are selected on the basis of planned structural layout, geology, and the size of a subsurface feature of importance to the site behavior. The CPT data are reviewed usually in the field, and the depths of correlation/verification samples are determined. The number of samples are reduced to the minimum required to characterize each critical stratum; exploration dollars are spent on obtaining high quality samples rather than on a high volume of samples.

Not all strata need to be routinely sampled. For example, a dense sand deposit is unmistakeble from the CPT, and if liquefaction is the concern of the investigation then no further tests will be required. However, if the strength of a clayey silt stratum is critical, then careful sampling and laboratory testing should supplement the CPT data. The CPT data can then be used to extrapolate the laboratory results across the site. Finally, if some characteristic of the soil is of importance which cannot be estimated from the CPT, for example, pH, then adequate samples should be obtained site wide.

3.0 CONTRACTING FOR CPT SERVICES

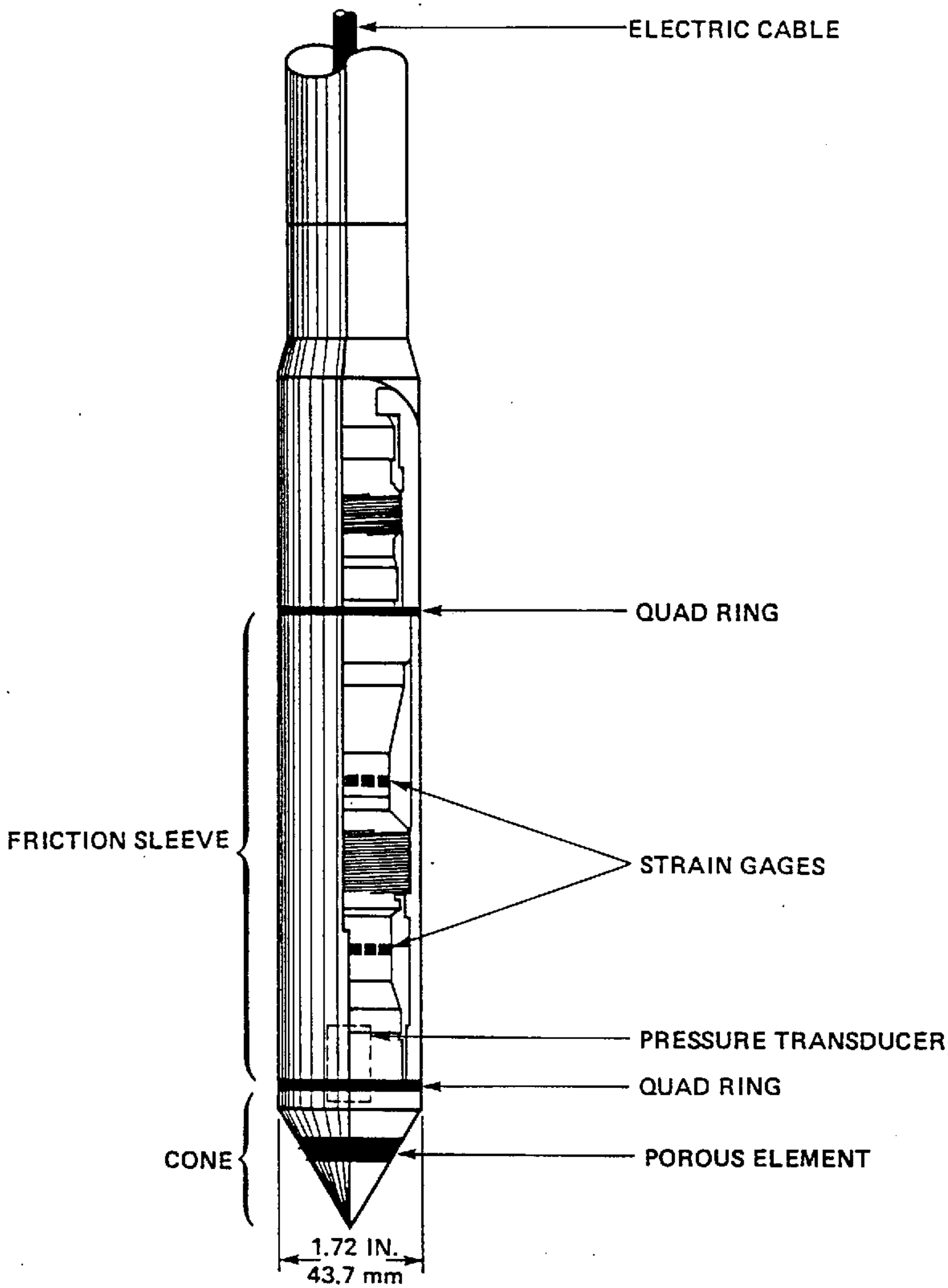
The best protection that a user of CPT services can have against a poor field program or inadequate data is to know the consultant/contractor who provides the service. It is virtually impossible to contractually prevent a substandard service. However, there are guidelines that can be applied to the contracting process to help ensure an appropriate service. The application of these guidelines requires some familiarity with either the supplier of the service or with the CPT method itself. Although there is an ASTM standard for the CPT (ASTM D3441-79), the standard alone cannot ensure the adequacy of service.

3.1 Equipment

The equipment to be used should be specified as to electrical or mechanical cone, the reaction mass available for pushing (not necessarily the same as the system weight or hydraulic system capacity), and the type of data logging. If specifying electrical cones, the specific sensors needed such as tip, sleeve, inclination, seismic and piezometer should also be specified. Electrical cone instruments are typically available in at least two sensitivities; high sensitivity for measurements in very soft soils and normal sensitivity for the broad spectrum of penetratable soils. A typical multi-channel instrument is shown in Figure 1 and brief descriptions of the use of the different sensors is given in Table 1.

3.2 Calibration

The contract should require documentation of general procedures used to calibrate the instruments and obtain the data. This includes requiring proof that the instruments are periodically subjected to measurement of the calibration errors, including repeatability, non-linearity, zero load, and hysteresis errors. These terms are defined in Figure 2.



CONE PENETRATION TESTING

15 TON ELECTRIC FRICTION CONE INSTRUMENT WITH TIP SENSING PORE PRESSURE ELEMENT

Figure 1

TABLE 1

TYPES OF CPT SENSORS

1. Standard CPT (cone end bearing and friction sleeve)
   - measures soil resistance to mechanical penetrations, in bearing and sliding shear failure modes.

2. Piezometric CPT (addition of pore pressure sensor)
   - measures soil pore pressure response to mechanical penetration; can be used to obtain ambient pore pressures and an indication of permeability. Two designs are common: ported through cone tip or ported through front of sleeve. These designs give radically different measurements, especially in stiff soils.

3. Resistivity CPT (addition of electrical field measurement)
   - measures electrical resistance of soil around CPT instrument; responds to degree of saturation and electrolyte type.

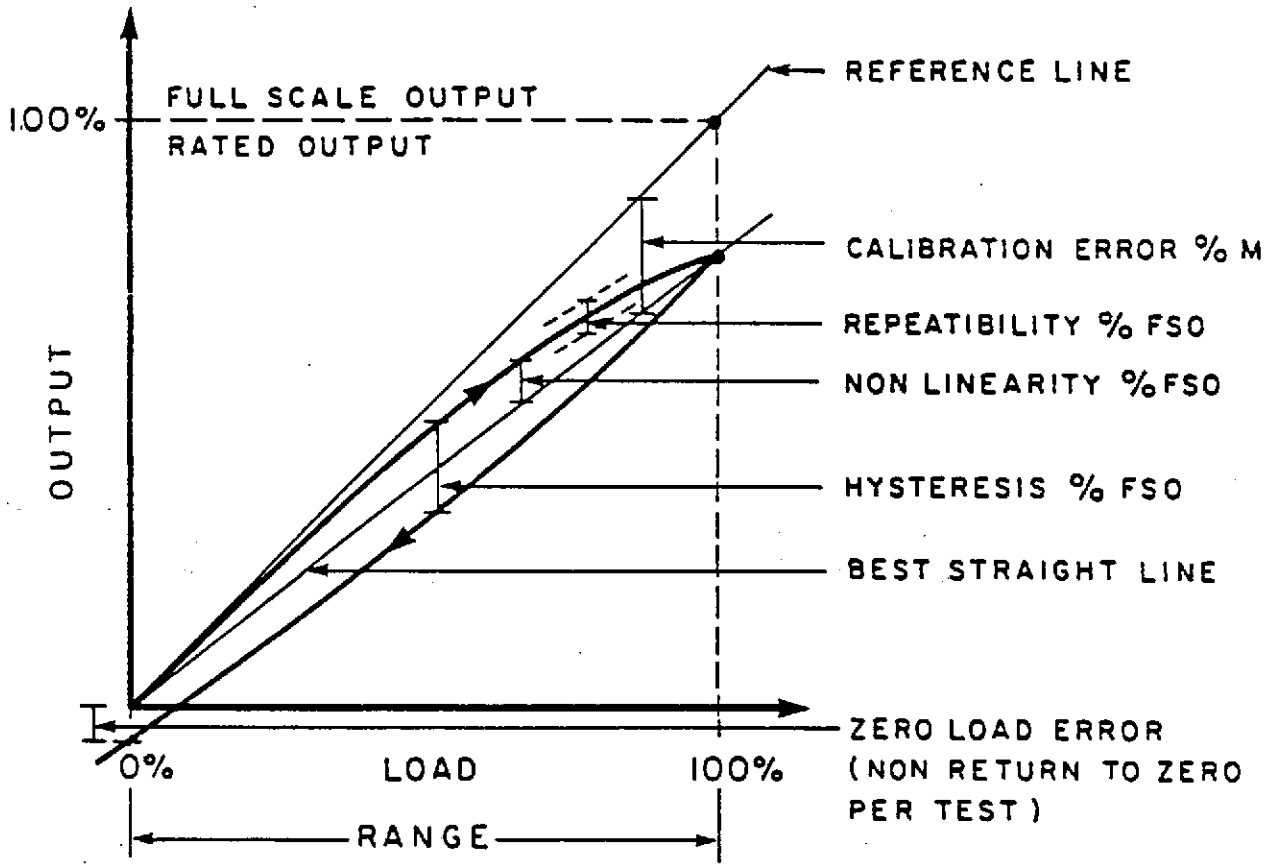
4. Thermal CPT (addition of thermistors)
   - measures soil thermal response to mechanical penetration; can be used to determine ambient temperatures.

5. Seismic CPT (addition of geophones)
   - measures soil response to surface seismic excitation, with superior sensor-soil coupling. Down hole and crosshole tests may be performed.

6. Nuclear CPT (addition of nuclear moisture-density-source)
   - measures soil response to low level radiation, indicating in situ densities and moisture content.

7. Pressuremeter CPT (addition of a pressuremeter cell)
   - measures radial response of soil to radial expansion and contraction of cell.

8. Fluid Sampler CPT (addition of lysimeter)
   - allows acquisition of select or continuous samples of in situ gases or liquids.



% FSO PERCENTAGE OF FULL SCALE OUTPUT
% M PERCENTAGE OF MEASURED OUTPUT

DEFINITION OF TERMS TO CALIBRATE (6)

FIGURE 2

3.2.1 Operational Checking

The data report should reference these procedures and typical values and should include a statement of the difference between at least one field calibration. Further, the zero load error at the end of each test should be noted. If tests are performed under water, then the response of the sensor to hydrostatic pressures must also be determined and reported.

3.2.2 Piezocone Saturation

Special attention must be given in the contract to use of documented procedures for saturation of the piezometer element that is used. Lack of saturation will result in highly misleading data. Further, there is at this time little guarantee, and no certain way to check, that the element will remain saturated during the penetration process. Loss of saturation can result from the interaction of location and type of porous element, saturating fluid, soil density and soil degree of saturation. The most reliable way to obtain good piezometer data is through pre-project discussion with a reputable service during which procedures appropriate to the project needs can be defined. For example, Earth Technology has, on many projects, installed casing with the CPT truck to below the water table in order to reduce the possibility of piezometer saturation loss in unsaturated soils above the water table.

3.2.3 CPT Operator

The actual performance of a CPT test requires a highly trained, competent individual who is responsive to the test characteristics and the geologic environment that he is testing. Although the CPT is relatively operator independent, compared to the SPT for instance, a knowledgable, observant operator can maximize the quality of the results. In particular the operator should be capable of fully calibrating the instrument during a job if needed, performing field inspections and repairs of instruments and electronics, and fully documenting the test.

3.3 Data Presentation

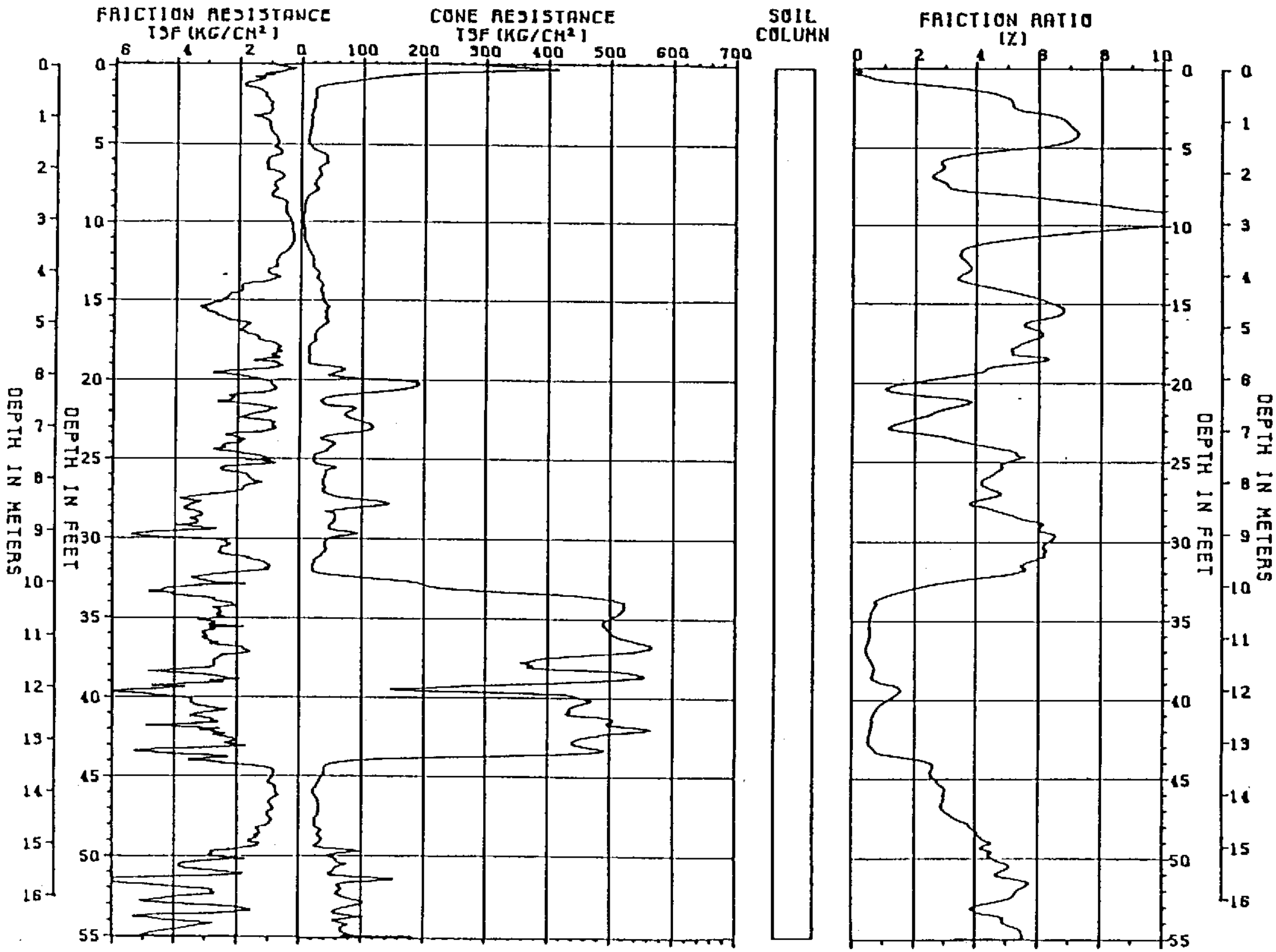
The minimum depth interval at which data are obtained from each sensor, typically 2.0cm, should be specified. Likewise, the scales at which measured and interpreted data are to be reported should be specified. Typically the basic data should be shown as continuous plots of tip bearing, sleeve friction, and pore pressure if obtained, in TSF, kg/cm^2, or other as desired, versus depth in feet or meters. Inclination is usually expressed simply as a single value indicating maximum inclination observed during the test.

Standard data processing should include generation of a continuous plot of friction ratio, and pore pressure ratio if obtained, versus depth at specified scales, as shown, for example, in Figure 3. The offset distances representative of physical dimensions of the instrument and used in the calculation of these ratios shoud be noted in the report, as should any filtering or averaging of the data.

Other basic information that should usually be included in a report includes tabulation of depth and measured and calculated values, typically at a one foot interval, as well as interpreted information such as Soil Behavior Type, Equivalent SPT N_1 values, Cyclic Strength, and Equivalent Drained Friction Angle or Undrained Strength, and Equivalent Relative Density. An example of such a tabulation is given in Figure 4. The contract specification should always require description of the method used to develop such interpreted data.

3.4 Report

Final report contents should be specified. That report, in summary, would include documentation of time and location of each test, equipment used, depths achieved, refusal criteria invoked, (target depth achieved, total capacity exceeded, rod buckling initiated, see Table 2) documentation of calibration and saturation procedures and field checks of calibrations, maximum test inclination, plots of the measured and interpreted values. An example of a



PROJECT: TAMU
PROJECT NUMBER: 84-104-17
INSTRUMENT NUMBER: F15CKE070
DATE: 15 AUGUST 1984

The Earth Technology Corporation

CONE PENETROMETER TEST

FIGURE 3 — TYPICAL SOUNDING LOG

DEPTH FT	CONE TSF	FRICTION TSF	FRIC RATIO	SOIL BEHAVIOR TYPES	EQUIV RELATIVE DENSITY	EQUIV FRIC ANGLE	EQUIV SPT	EQUIV N1'	SU1= (C-T)/NC KSF	SU2= FS*A KSF
1.0	96.78	1.31	2.69	SANDY SILT-CLAYEY SILT	80-100	35-39	61	65		
2.0	24.16	1.19	5.14	CLAY	UNDEF	UNDEF	20	27	3.43	2.38
3.0	16.20	1.03	6.69	CLAY	UNDEF	UNDEF	20	27	2.29	2.06
4.0	14.10	1.02	7.26	CLAY	UNDEF	UNDEF	19	26	1.98	2.04
5.0	12.99	0.77	5.30	CLAY	UNDEF	UNDEF	13	20	1.81	1.54
6.0	39.88	1.10	2.88	CLAYEY SILT-SILTY CLAY	60-80	27-31	20	25	5.65	2.20
7.0	30.92	0.55	2.61	CLAYEY SILT-SILTY CLAY	60-80	27-31	15	21	4.36	1.10
8.0	22.51	0.87	5.61	CLAY	UNDEF	UNDEF	21	28	3.15	1.74
9.0	4.86	0.47	10.12	ORGANIC MATERIALS	UNDEF	UNDEF	10	17	0.62	0.94
10.0	2.72	0.30	9.44	ORGANIC MATERIALS	UNDEF	UNDEF	7	14	0.30	0.60
11.0	5.56	0.22	4.33	CLAY	UNDEF	UNDEF	5	12	0.70	0.44
12.0	16.79	0.63	3.58	SILTY CLAY TO CLAY	UNDEF	UNDEF	11	18	2.30	1.26
13.0	25.46	1.06	3.55	SILTY CLAY TO CLAY	UNDEF	UNDEF	16	23	3.53	2.12
14.0	35.50	1.90	4.77	CLAY	UNDEF	UNDEF	33	40	4.95	3.80
15.0	37.99	2.51	6.57	CLAY	UNDEF	UNDEF	52	59	5.30	5.02
16.0	40.48	2.52	5.74	CLAY	UNDEF	UNDEF	41	48	5.65	5.04
17.0	23.95	1.76	6.06	CLAY	UNDEF	UNDEF	33	40	3.28	3.52
18.0	13.18	0.72	5.17	CLAY	UNDEF	UNDEF	13	20	1.73	1.44
19.0	17.56	0.70	4.35	CLAY	UNDEF	UNDEF	14	21	2.35	1.40
20.0	166.74	1.20	1.59	SAND TO SILTY SAND	60-80	39-42	58	60		
21.0	56.83	2.27	3.75	CLAYEY SILT-SILTY CLAY	80-100	27-31	40	47	7.94	4.54
22.0	79.69	1.03	2.41	SANDY SILT-CLAYEY SILT	60-80	31-35	40	43		
23.0	118.64	0.76	1.65	SILTY SAND TO SANDY SILT	60-80	35-39	50	52		
24.0	57.83	1.87	4.56	SILTY CLAY TO CLAY	UNDEF	UNDEF	53	60	8.06	3.74
25.0	22.54	0.90	4.94	CLAY	UNDEF	UNDEF	20	27	3.01	1.80
26.0	41.60	1.68	4.27	SILTY CLAY TO CLAY	UNDEF	UNDEF	35	42	5.72	3.36
27.0	36.08	1.88	4.81	CLAY	UNDEF	UNDEF	33	40	4.92	3.76
28.0	106.95	3.55	4.64	*SANDY CLAY TO CLAY	UNDEF	UNDEF	100	100		
29.0	54.61	3.21	6.11	CLAY	UNDEF	UNDEF	72	79	7.55	6.42
30.0	47.37	4.04	6.31	CLAY	UNDEF	UNDEF	61	68	6.51	8.08
31.0	34.83	2.47	6.05	CLAY	UNDEF	UNDEF	40	47	4.71	4.94
32.0	20.19	0.98	5.16	CLAY	UNDEF	UNDEF	82	83	2.61	1.96
33.0	208.18	3.09	1.91	SILTY SAND TO SANDY SILT	80-100	39-42	82	83		
34.0	525.13	2.59	0.76	GRAVELLY SAND TO SAND	80-100	>45	100	100		
35.0	505.60	2.36	0.57	GRAVELLY SAND TO SAND	60-100	>45	100	100		
36.0	503.32	3.09	0.56	GRAVELLY SAND TO SAND	80-100	>45	100	100		
37.0	552.88	1.81	0.44	GRAVELLY SAND TO SAND	80-100	>45	100	100		
38.0	376.87	2.72	0.72	GRAVELLY SAND TO SAND	60-80	42-45	82	82		
39.0	450.74	2.82	1.11	*GRAVELLY SAND TO SAND	80-100	42-45	100	100		
40.0	452.16	3.93	1.15	*GRAVELLY SAND TO SAND	80-100	42-45	100	100		
41.0	430.45	3.00	0.66	GRAVELLY SAND TO SAND	80-100	>45	100	100		
42.0	566.79	2.51	0.58	GRAVELLY SAND TO SAND	80-100	>45	100	100		
43.0	447.61	2.07	0.68	GRAVELLY SAND TO SAND	80-100	>45	100	100		
44.0	90.37	3.51	2.59	SANDY SILT-CLAYEY SILT	80-100	35-39	51	52		
45.0	36.35	0.81	2.73	CLAYEY SILT-SILTY CLAY	60-80	27-31	18	22	4.81	1.62
46.0	22.18	0.76	2.97	CLAYEY SILT-SILTY CLAY	40-60	27-31	14	19	2.77	1.52
47.0	31.95	0.81	3.02	CLAYEY SILT-SILTY CLAY	60-80	27-31	18	22	4.16	1.62
48.0	24.63	0.96	3.87	SILTY CLAY TO CLAY	UNDEF	UNDEF	18	25	3.11	1.92
49.0	36.57	1.61	4.53	SILTY CLAY TO CLAY	UNDEF	UNDEF	33	40	4.80	3.22
50.0	41.55	2.87	4.60	SILTY CLAY TO CLAY	UNDEF	UNDEF	40	47	5.51	5.74
51.0	52.64	2.38	4.63	SILTY CLAY TO CLAY	UNDEF	UNDEF	50	57	7.11	4.76
52.0	67.80	3.67	5.32	*SANDY CLAY TO CLAY	UNDEF	UNDEF	80	85		
53.0	102.77	3.89	3.86	*SANDY CLAY TO CLAY	UNDEF	UNDEF	56	63		
54.0	54.72	4.35	4.96	CLAY	UNDEF	UNDEF	80	86	7.35	8.70
55.0	100.50	5.14	5.51	*SANDY CLAY TO CLAY	UNDEF	UNDEF	100	100		

"*" INDICATES "OVERCONSOLIDATED OR CEMENTED MATERIAL"

TYPICAL DATA TABULATION
FIGURE 4

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TABLE 2

CPT Refusal

Type	Cause	Indications	Remedial Actions
Reaction force exceeded	Cumulative rod friction and/or penetration of very hard layer. Most common limitation encountered in CPT.	Deadweight liftoff, earth anchor yield.	Use heavier equipment (maximum available ~20T trucks). Use larger and/or deeper earth anchors. Use more efficient friction reducers (enlarged instruments). Drill through hard layer, if known to be thin, and resound.
Push rod buckling	Inadequate lateral support (Q_c<10 TSF) to push rods, column buckling. Occasional occurrence in recent, swamp or backwater organic deposits, or silty hydraulic fill.	Bowing of push rods, excessive push rod springback after hard push. Snapping sound and loss of electrical signal.	Set casing through soft layer with CPT equipment, if layer extent is limited (maximum about 25 ft.).
Rapid change in inclination (>1°/inch)	Deviation due to bedding, gravels, cobbles, rubble or sloping bedrock. Also caused by not leveling CPT equipment before test.	Inclinometer readings. Snapping sound and loss of electrical signal.	Use inclinometers. Terminate test and resound.

summary report table is given in Figure 5. Ideally, the report would include a brief review of the data by the consultant with particular emphasis on any apparent peculiarities or abnormal conditions.

In summary, it can be noted that the ultimate quality of the CPT service received can better be ensured by knowing and working with the consultant/contractor than by contractual specification alone.

TEST NUMBER	DATE	DEPTH	REFUSAL* CRITERIA	MAXIMUM INCLINATION	INSTRUMENT** NO. TYPE	ZERO LOAD ERROR (q/fs) TSF	ONE PT. CALIB ERROR
1	10 Aug. 84	84.5	C	8°	15 ECF P-72	6.5/0.07	+2.0%
2	10 Aug. 84	77.0	C	8°	15 ECF P-72	2.0/0.04	+0.5%
3	10 Aug. 84	86.0	C	5°	15 ECF P-72	0.5/0.02	+0.1%
4	11 Aug. 84	82.5	C	6°	15 ECF P-73	4.0/0.04	+3%
5	10 Aug. 84	51.5	C	19°	15 ECF P-72	1.0/0.02	-0.03%
6	10 Aug. 84	92.0	C	8°	515 ECF P-72	2.0/0.04	±0%
7	10 Aug. 84	102.0	T	23°	515 ECF P-72	1.0/0.02	+0.3%
8	11 Aug. 84	101.5	T	11°	515 ECF P-73	2.0/0.02	-0.6%
9	11 Aug. 84	100.0	T	7°	515 ECF P-73	1.0/0.01	+0.3%
10	11 Aug. 84	102.5	T	13°	515 ECF P-73	3.0/0.03	-0.4%

*C = Reach 20 T Capacity
T = Target Depth Achievers
B = Rod Buckling

**15-15T Load Cell, 15 sq. cm. end area
515-5T Load Cell, 15 sq. cm. end area
510-5T Load Cell, 10 sq. cm. end area

E = Electric
C = Cone
F = Friction
P = Piezometer, Tip

PS= Piezometer, Side
R = Resistivity
T = Temperature
S = Seismic

TYPICAL SUMMARY REPORT TABULATION

FIGURE 5

4.0 INTERPRETATION OF CPT DATA

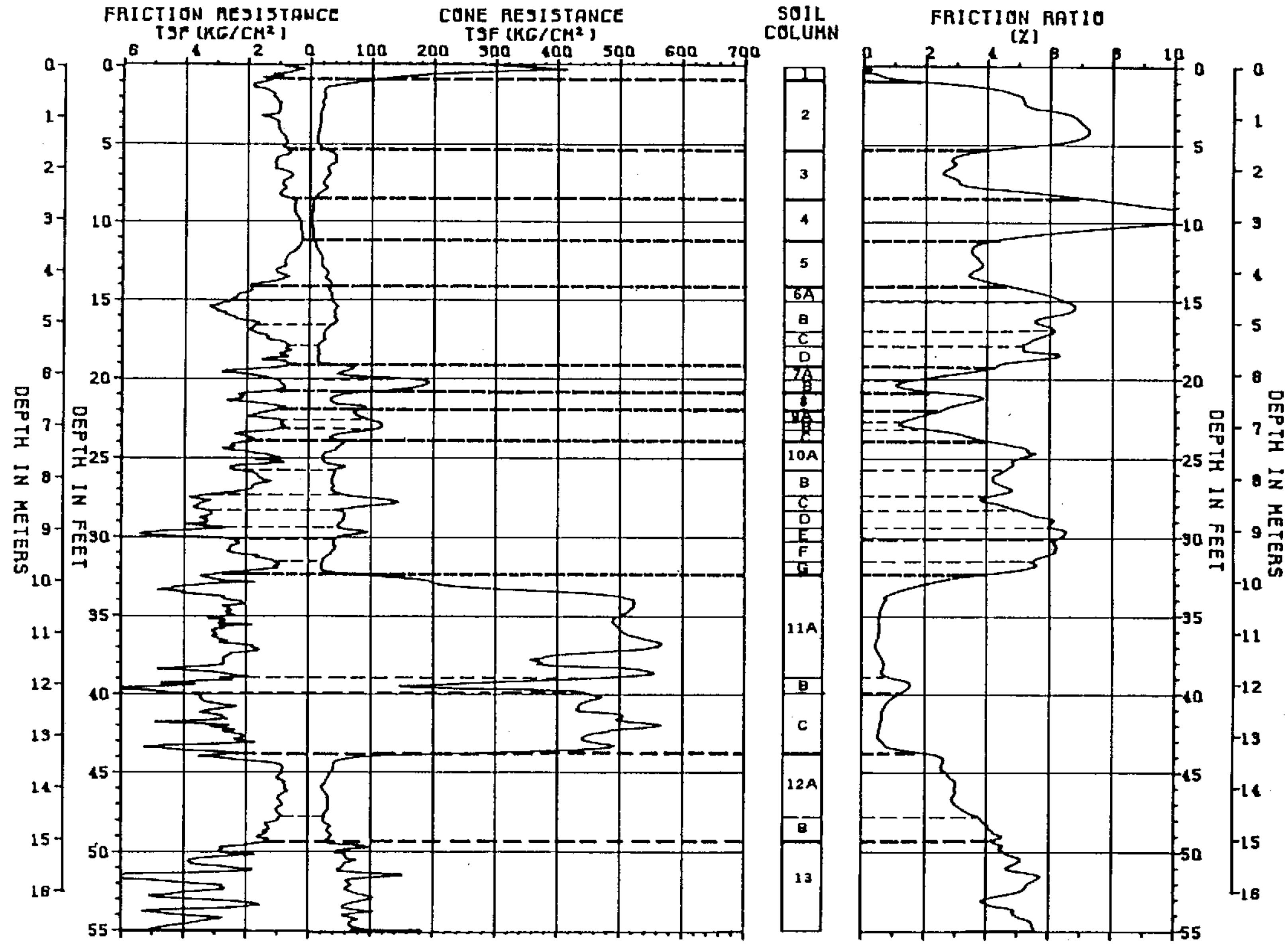
Interpretation of CPT data and application of the results to soil mechanics or foundation design problems is the topic of intense research worldwide. There is no single source of information that provides step by step instructions for CPT data interpretation applicable to all cases. Further, as the CPT provides only a few channels of information while many variables can influence soil behavior, there will never be a single interpretive procedure that meets all project requirements. However, through proper use of the CPT data much valuable insight into site characteristics can be gained.

4.1 Stratigraphy

The first step in CPT interpretation is to get to know the site. Review the geology and then quickly review the CPT data to develop an overview of conditions. Re-examine what information is likely to be critical to the project. Then begin detailed assessment of the individual CPT sounding logs.

The continuous CPT data logs are the primary and most valuable source of information obtained from the test. Data conversions such as interpreted soil properties are always supplemental. Review and mark each channel of each log separately, looking for changes in magnitude and characteristic of the log, such as smoothness or frequency of response. Prepare a stratigraphic sequence based upon compilation of all the changes in magnitude and characteristic evidenced in each log. An example of such a stratigraphic delineation is given in Figure 6. Check for material similarity between different strata by examining where the strata fall on a cross plot of end bearing and friction ratio. Then check for continuity of end bearing magnitude between similar strata found at different depths.

Horizontal continuity of strata is usually of importance to the site characterization process even if only to allow extrapolation of laboratory data across the site. A detailed horizontal profile can be developed from the



PROJECT: TAMU
PROJECT NUMBER: 84-104-17
INSTRUMENT NUMBER: F15CKE070
DATE: 15 AUGUST 1984

The Earth Technology Corporation

CONE PENETROMETER TEST

STRATIGRAPHIC DELINEATION

FIGURE 6

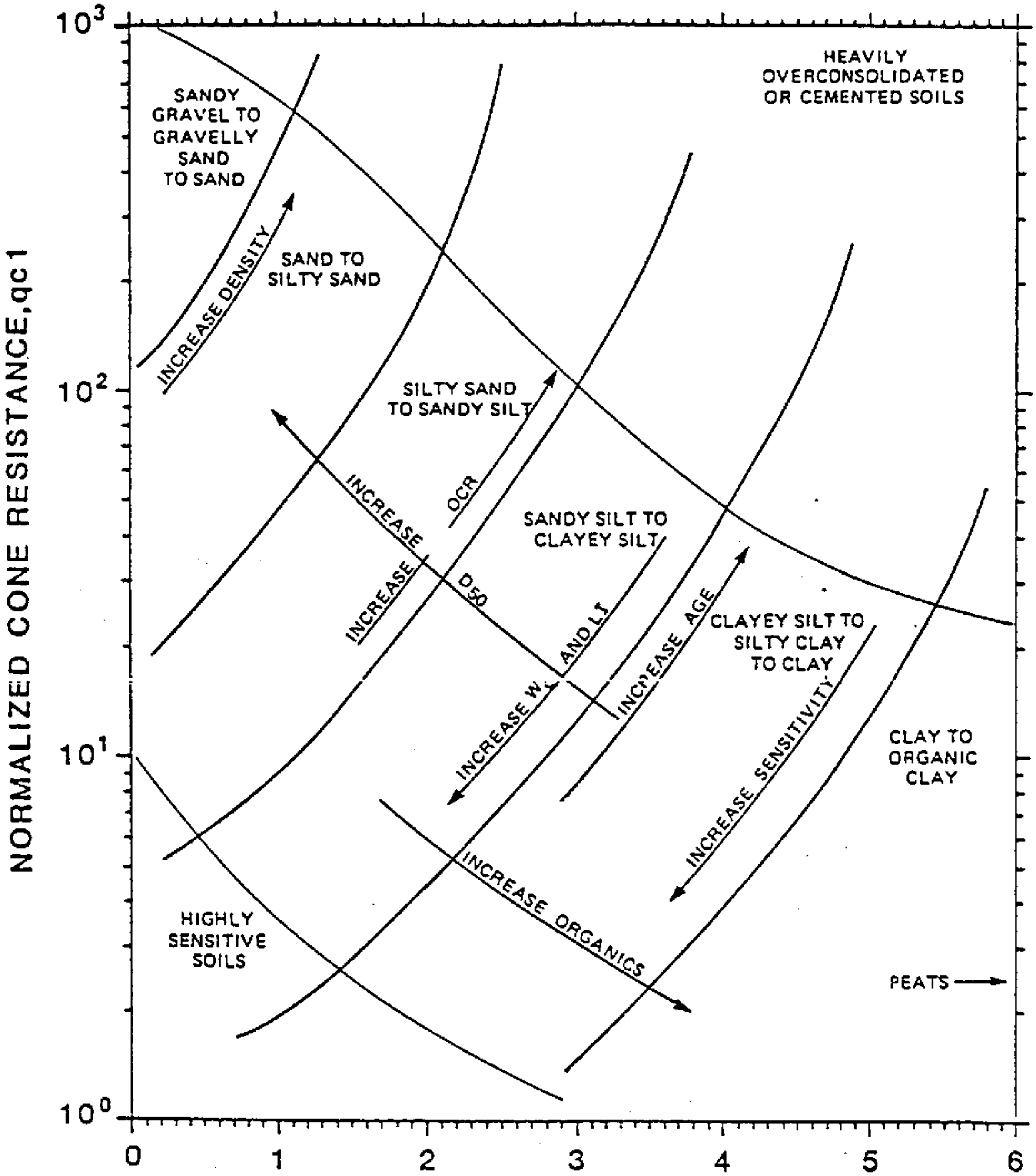
individual logs laid side by side or from a computer-drawn profile series. Establish layer continuity based upon the similarity of individual strata identified within each CPT coupled with an understanding of the likely geologic processes that have affected those strata. Compare strata with those revealed by borings. Note that borings typically provide a very simplified picture of actual conditions and disagreements between borings and CPTs invariably are the result of a poor boring log.

4.2 Soil Properties

After an appropriate layering model is defined, utilize the Soil Behavior Type classification and properties identification charts shown in Figures 7 through 9, or other similar information, to describe each strata. Preliminary engineering analyses should be performed utilizing those initial properties assessments. The analyses will identify problems or critical areas requiring further attention. Select a laboratory testing program to provide site specific correlation for the critical areas and areas of interest as needed.

Earth Technology's extensive CPT data base is stored on computer so that the results of laboratory tests can be compiled directly onto the CPT-Soil Behavior Type classification chart. That compilation allows the laboratory results to be applied to any other area of the site having CPT values which fall in that same end bearing and friction ratio zone of the classification chart of Figure 7.

The information contained in the charts of Figures 7 through 9 is most appropriate for geologically young saturated soils. Uncertainties associated with use of the Soil Behavior Type chart are the similar behaviors that can be evidenced by slightly different mixtures of different grain sizes and the effects of underconsolidation or heavy cementation upon the penetrometer readings. Testing in unsaturated or otherwise unusual soil conditions usually requires site- or region-specific correlations until a level of familiarity with those materials is developed.



SOIL BEHAVIOR TYPE CLASSIFICATION CHART

FIGURE 7

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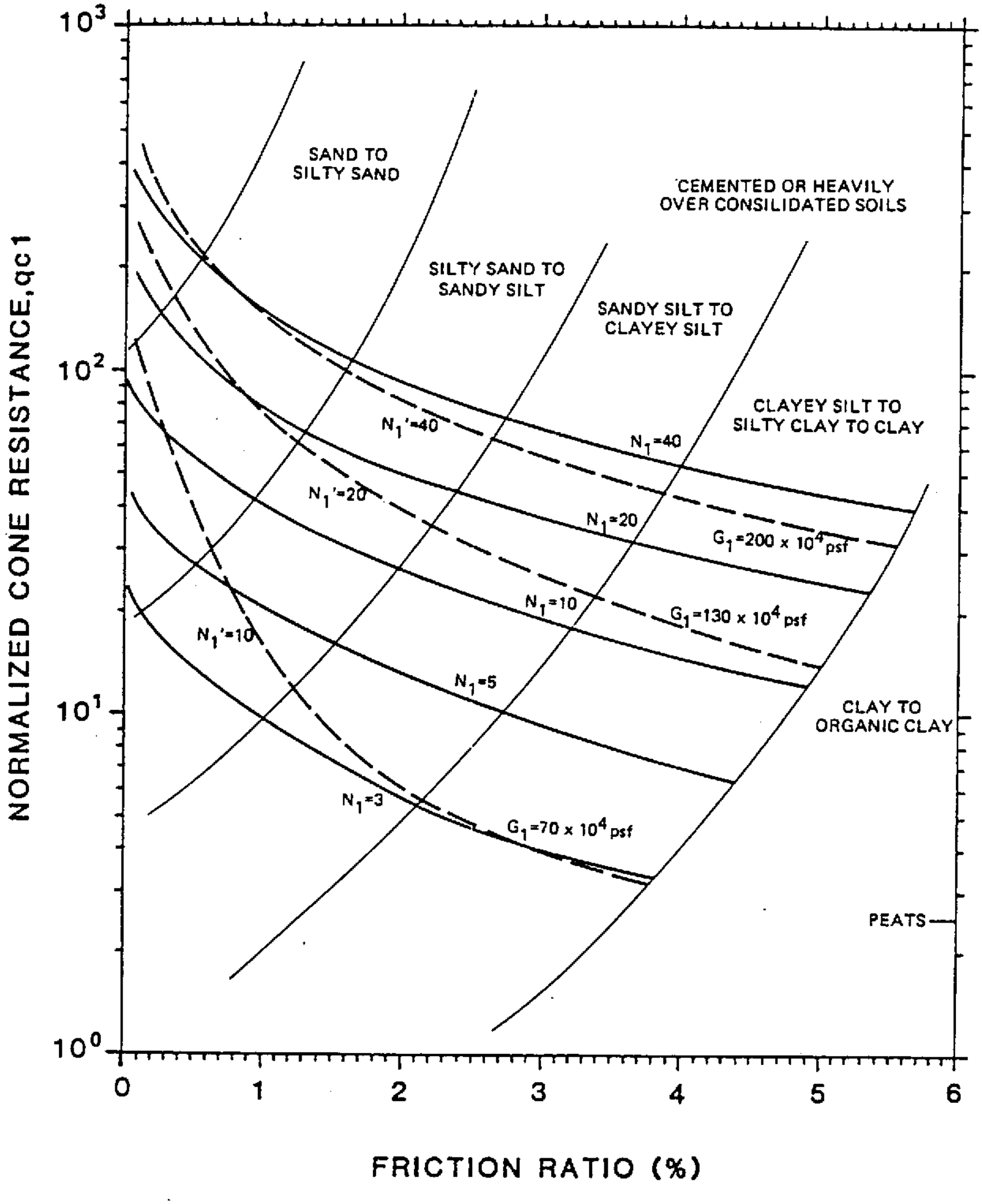
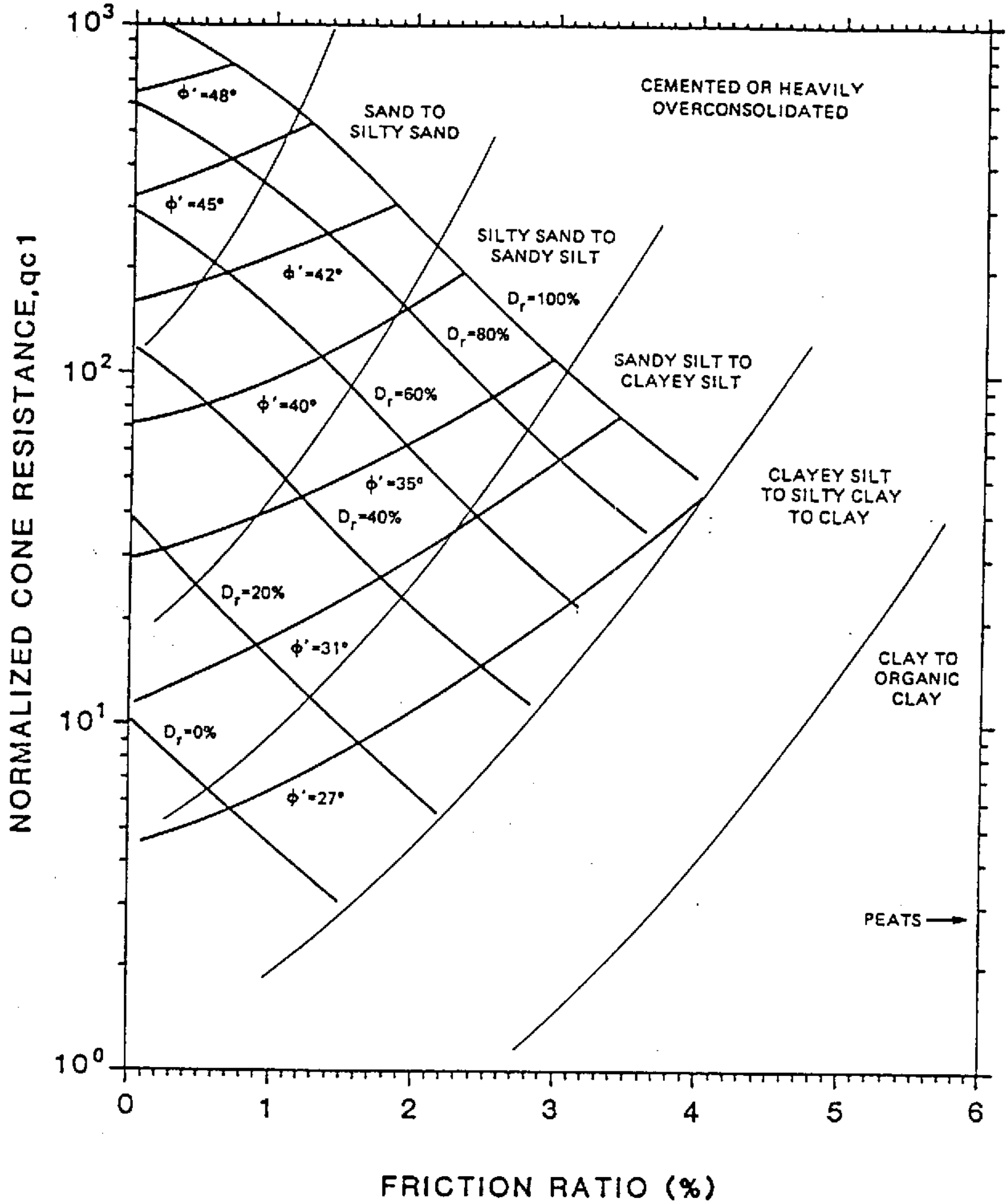


EXPANDED SOIL BEHAVIOR TYPE CLASSIFICATION CHART SHOWING OVERBURDEN NORMALIZED EQUIVALENT SPT N VALUES (55% ENERGY) AND FINES-CONTENT ADJUSTED N- VALUES AND MAXIMUM SHEAR MODULI TRENDS

FIGURE 8

The Earth Technology Corporation



EXPANDED SOIL BEHAVIOR TYPE CLASSIFICATION CHART WITH EQUIVALENT OVERBURDEN NORMALIZED FRICTION ANGLE AND RELATIVE DENSITY TRENDS

FIGURE 9

The Earth Technology Corporation

The set of classification charts in Figure 7 through 9 have been developed based upon extensive correlation with overburden normalized cone end bearing (9) and friction ratios. Usually it is not necessary to actually carry out such normalization except when precision is important or when data was obtained at shallow (less than 5 feet) or great (greater than 50 feet) depths.

Once soil type and general soil consistency are known, almost any other soil property can at least be estimated. Thus in any project the adequacy of the CPT regional correlation with soil type should be reviewed before attempting any other interpretation. The review of correlation adequacy should focus on prediction of soil behavior and not prediction of arbitrary soil names.

4.3 CPT-SPT

The CPT-Standard Penetration Test (SPT) correlation chart shown in Figure 8 is considered representative of the correlation between CPT and a 55 percent efficient trip hammer SPT used with a liner-sample without liners. Because of the similarity in penetration mechanism between the CPT and SPT, the CPT-SPT correlation need not be modified for regional conditions. However, the correlation can be modified to provide equivalent SPT values appropriate for some other SPT energy efficiency.

Depth normalization can be performed using any of the numerous overburden adjustment relations (C_n) developed over the years. The range of published relations and the lack of any data regarding overburden correction in other than clean sand effectively invalidates claims of greater appropriateness of any one method over another (21).

4.4 Cyclic Strength

The CPT-cyclic strength correlation shown in Figure 8 was developed by Earth Technology following the simplified SPT method (24). The predicted strengths utilizing this CPT approach have been directly verified by field observation of liquefaction at sites at which CPT measurements were taken (23). This CPT approach provides continuous prediction of fines-content-adjusted equivalent SPT values which can directly be utilized in available SPT-cyclic stress ratio correlations (24).

4.5 Modulus

CPT-Shear Modulus correlations shown in Figure 8 were again based upon SPT-Shear Modulus correlations available in the literature and upon actual CPT versus field and laboratory measured shear moduli (28). However, this data base is not extensive and predicted values should be used with some caution. Numerous other correlations can be found in the referenced literature; however, most such correlations are appropriate only for a single soil type.

4.6 Friction Angle and Relative Density

CPT-equivalent drained friction angle and Relative Density correlations shown in Figure 9 have been based upon data available in the referenced literature and adjusted through limited laboratory correlation (13). Although caution should be used in applying such correlations, the general magnitude of the parameters has been found to agree well with the predicted values. Improvements in such correlations have been slow because of the difficulty in obtaining undisturbed samples of natural and lightly cemented sands and the inevitable inaccuracy associated with laboratory calibration tank-type CPT correlations.

4.7 Undrained Strength

Undisturbed undrained strengths (S_{uu}) of clay soils can be estimated using any of the bearing capacity-type relations found in the referenced literature. Such equations generally are of the form:

$$S_{uu} = (q_c - \sigma_t)/N_c$$

where q_c is the cone end bearing, σ_t is the total overburden stress and N_c is a bearing capacity factor. Cautions associated with using this formula are primarily related to degree of drainage existing during the test.

The appropriate bearing capacity factor, N_c, for use in strength calculations had not been assessed for partially drained or partially saturated clays. However, in fully saturated clays it is generally found that N_c ranges between about 9 and 16 with the lower values corresponding to the moderately sensitive clays and the higher values corresponding to the moderately overconsolidated clays. Extremes in either direction have resulted in reported N_c values as low as 6 and as high as 25. Earth Technology has recently developed a data base relating N_c to both material type and consistency, or to zones of the CPT-Soil Behavior Type classification chart.

Direct use of the CPT sleeve friction values (f_s) can be made as an estimate of the large strain or residual strength (S_{ur}) of clays:

$$S_{ur} = Af_s$$

where A is a correlation factor typically assumed equal to 1.0. No data is available relating the proper value of A to soil type and consistency.

The ratio of the undisturbed strength calculated using the end bearing value (S_{uu}) to the large strain strength (S_{ur}) calculated from the sleeve friction can be used to define the sensitivity (S_t) of the soil:

$$S_t = S_{uu}/S_{ur}$$

This definition has been found to provide values which relate well to sensitivities obtained from the field vane test.

4.8 Foundation Design

General procedures for shallow and deep foundation design are contained in the references provided in the following section. Examination of the adequacy of each procedure is beyond the scope of this manual. Those references in general will be found to provide adequate description of uses and limitations of each procedure.

5.0 REFERENCES

There are thousands of papers documenting the various aspects of Cone Penetrometer Testing and interpretation. The following abbreviated list is intended to provide a first step in obtaining the detailed information desired.

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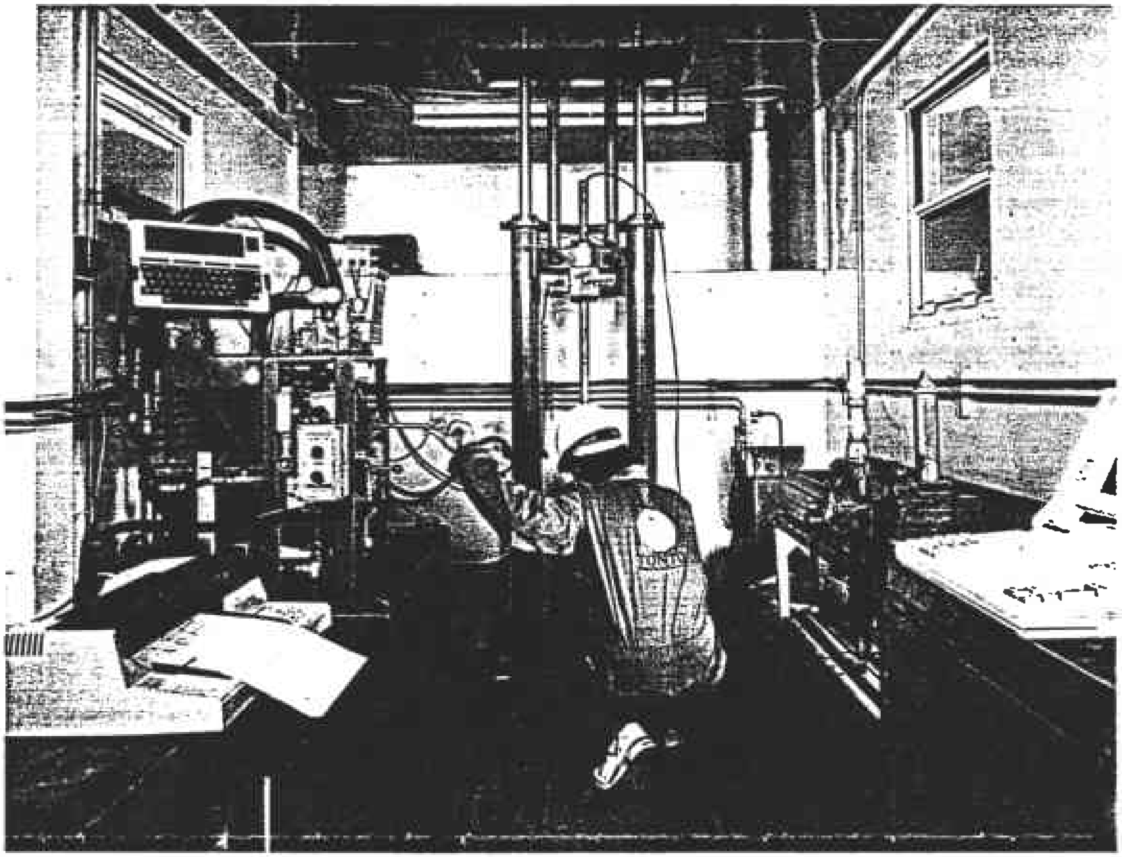
APPENDIX B

IN-SITU SOIL SAMPLING

TONTO®
DRILLING SERVICES, INC.
ENVIRONMENTAL AND GEOTECHNICAL DIVISION

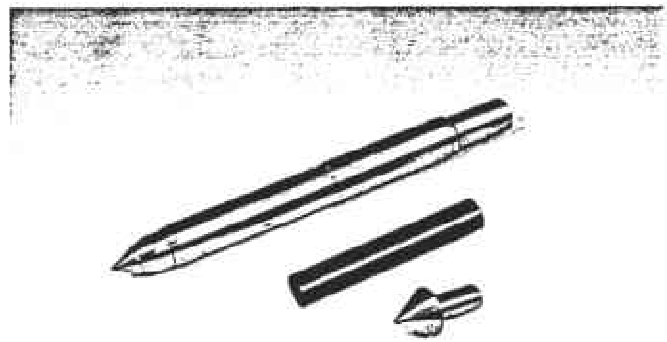
INSITU TESTING SERVICES



The cone penetration test is widely accepted as a low cost, non-destructive method of insitu testing for environmental site assessment and geotechnical site investigation. As a logging tool, this technique is unequalled with respect to the delineation of stratigraphy and the nearly continuous, rapid measurement of tip and friction resistance, as well as pore pressure.

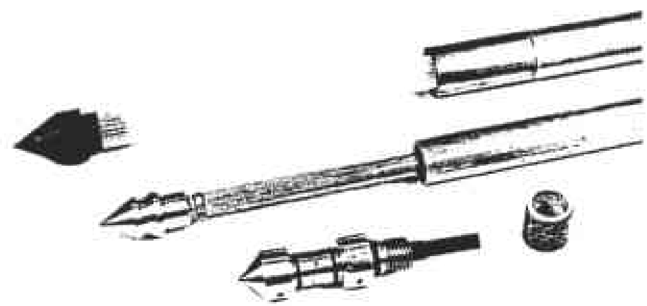
Our Cone Rigs are mounted on all-wheel-drive trucks which are capable of travel at highway speeds. The hydraulic push system has 20-Ton capacity and data is recorded by an on-board computer.

Data is acquired at a rate of 1 meter/ minute with measurement increments of 5 centimeters. Measurements include tip and friction resistance, pore pressure, inclination and temperature which are printed immediately for inspection by the engineer/geologist. A report-ready plot of this data is also available.



Available groundwater sampling devices include the HydroPunch® and BAT® samplers. These tools are pushed to a target depth and a sample is retrieved from discrete intervals. Target depths defined by analysis of the real time CPT printout and plots greatly increase sampling efficiency. Other sampling techniques are available.

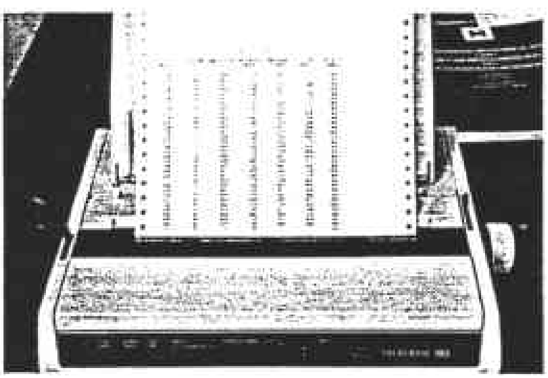
We have the capabilities of retrieving groundwater and soil samples for testing and visual verification of subsurface conditions.

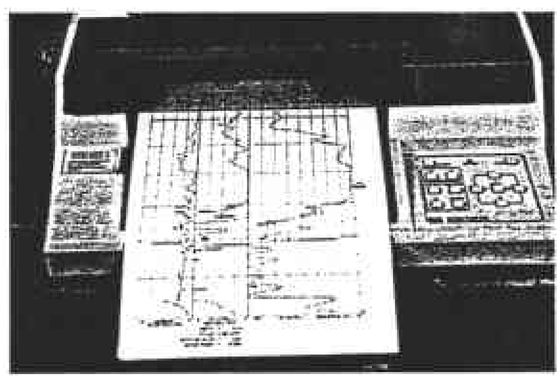


Soil samples suitable for chemical analysis are retrieved with a retractable cone tipped sampler.

Several alternatives are available for hole abandonment at environmentally sensitive sites.

With our highly trained crews and state-of-the-art equipment we can offer you these services at very competitive rates.





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APPENDIX C

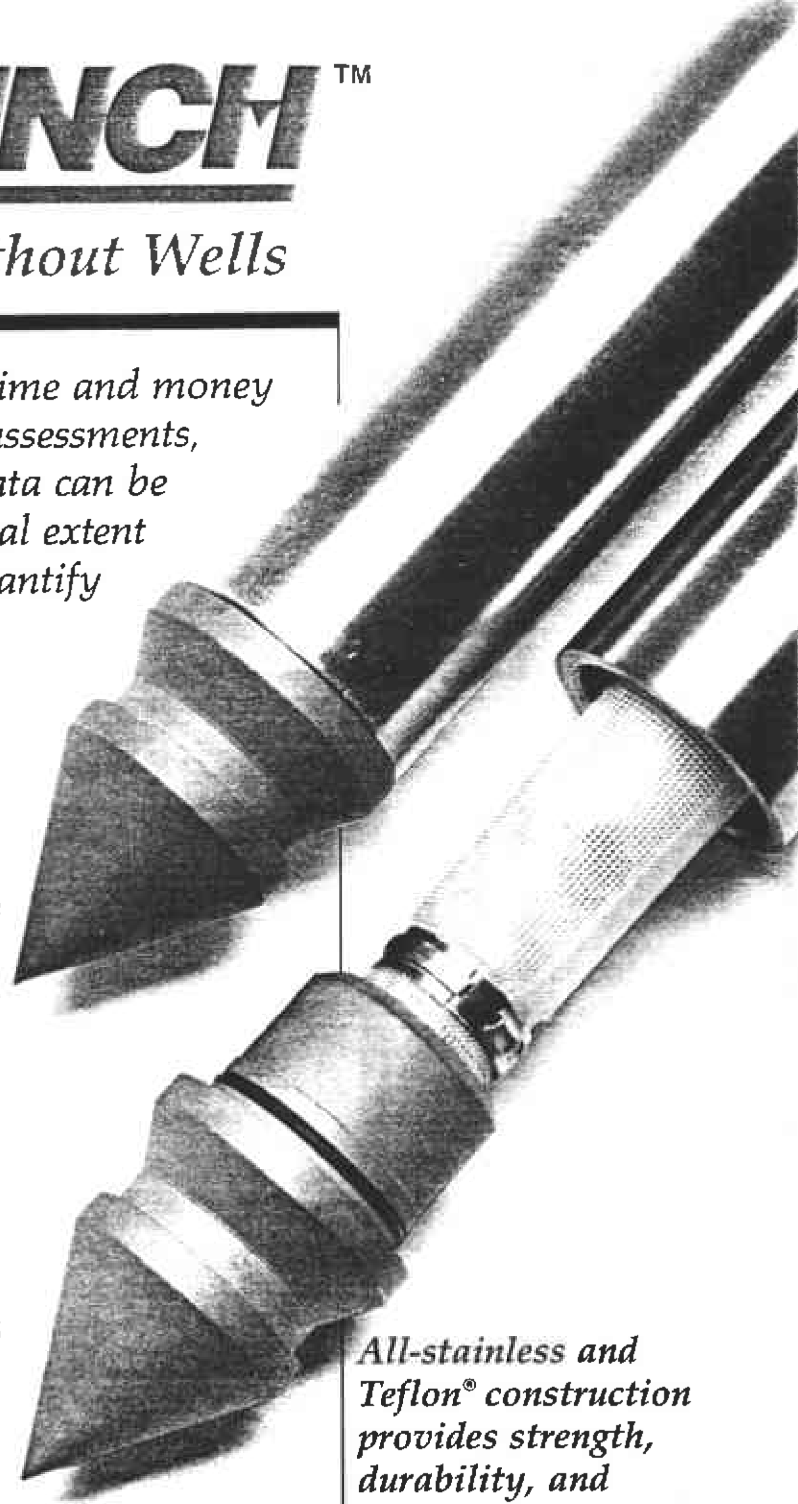
GROUNDWATER SAMPLING

HYDROPUNCH AND BAT SYSTEM

HydroPunch™

Groundwater Sampling without Wells

The HydroPunch™ drastically reduces time and money spent on groundwater monitoring site assessments, by collecting samples without wells. Data can be used to determine vertical and horizontal extent of contamination, and to accurately quantify pollutant concentration.



All-stainless and Teflon® construction provides strength, durability, and accurate samples uncontaminated by the testing procedure.

Samples in as little as one hour

The HydroPunch (U.S. Patent No. 4,669,554) is easily used with cone penetrometer or conventional drilling equipment. It collects up to 500 ml of groundwater at the desired depth in unconsolidated soil, and under many conditions can be used to sample multiple water-bearing zones in one operation. The HydroPunch can be visualized as working like a "driven" bailer.

Save 70% or more on site assessment costs

Extremely cost-effective, the HydroPunch has proven in field use to cost as little as 1/10 the price of drilling, casing, and developing a conventional well. The HydroPunch can also help determine optimum location for dedicated wells when they are required. More effective placement can minimize the number of permanent wells needed, providing long-term savings.

High-quality samples for accurate assessments

Samples are unaltered and uncontaminated by drilling fluids or cuttings. All-stainless and Teflon® construction makes the unit chemically inert, preventing contamination. In use, the HydroPunch is driven to the desired depth and then partially withdrawn, opening the inlet and isolating the collection zone from layers above and below. Replaceable inlet screen cartridges keep soil materials from entering the sample chamber.

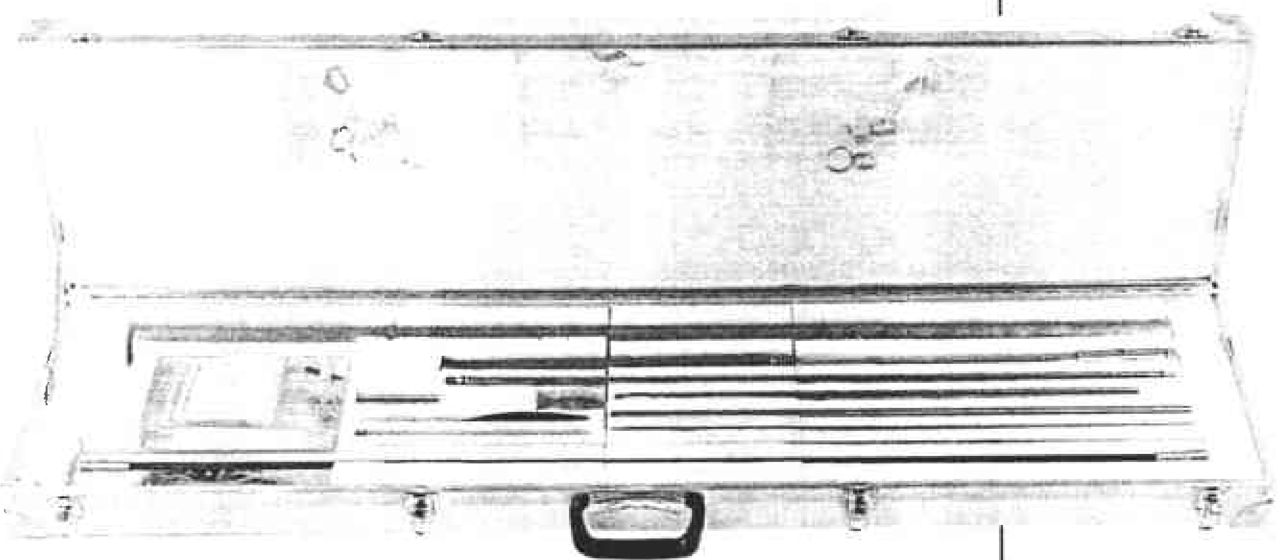
HydroPunch samples are consistent with requirements for all priority pollutants, unlike indirect site assessment techniques (i.e., soil gas sampling or geophysical monitoring). Samples are not affected by changes in soil type or other complicating factors. Easy field cleaning expedites repetitive sampling.

Environmentally safe

The HydroPunch can be operated with minimal disturbance to environmentally sensitive areas. There's no need to dispose of well development water, or of contaminated drill cuttings when used with a cone rig. The technique is unobtrusive and won't interfere with normal site operations.

QED Environmental Systems, Inc.

6095 Jackson Rd., P.O. Box 3726, Ann Arbor, MI 48106 800/624-2026 In Michigan, 313/995-2547 In Canada, 519/485-0290



Complete HydroPunch kit in heavy-duty carrying case

Specifications:

The HydroPunch™ is equipped with an "AW" box thread. Any sub-adapter or drive rod used with HydroPunch must have a minimum of 9/16″ inside diameter by 4″ deep above top of HydroPunch to allow clearance for top check. A number of adapters are available, allowing use of the HydroPunch with different types of drive rods.

The basic kit (shown above) includes one HydroPunch with barbed point in a sturdy, protective carrying case. The kit comes complete with water sample discharge device (w/Teflon® tubing and stopcock), cleaning brush set, extra O-ring and screen sets, extra stainless steel check balls, and all other accessories needed for use.

Maximum diameter: 1.75″	Length: Closed—64.50″	Open—76.50″
Weight (HydroPunch only): 24 lbs.	Shipping weight: 44 lbs.	
Sample volume: 500 ml (nominal)		

Guidelines for use:

General applications

The HydroPunch is a groundwater sampling tool designed to be pushed or driven to the desired depth for sample collection. It is manufactured for durable performance, with rugged construction of stainless steel and Teflon®. Following a few basic guidelines will maximize the usable life of your HydroPunch.

In general, the HydroPunch can be pushed or driven into position in the same types of formations suitable for a standard 2″ split barrel (spoon) soil sampler. Suitable geologic materials include unconsolidated clays, silts, sands, and fine gravels. Driving a split barrel sampler immediately above the desired HydroPunch sampling zone is helpful. This provides an estimate of soil permeability, and predicts the formation's resistance to driving the HydroPunch.

Hydrologic considerations

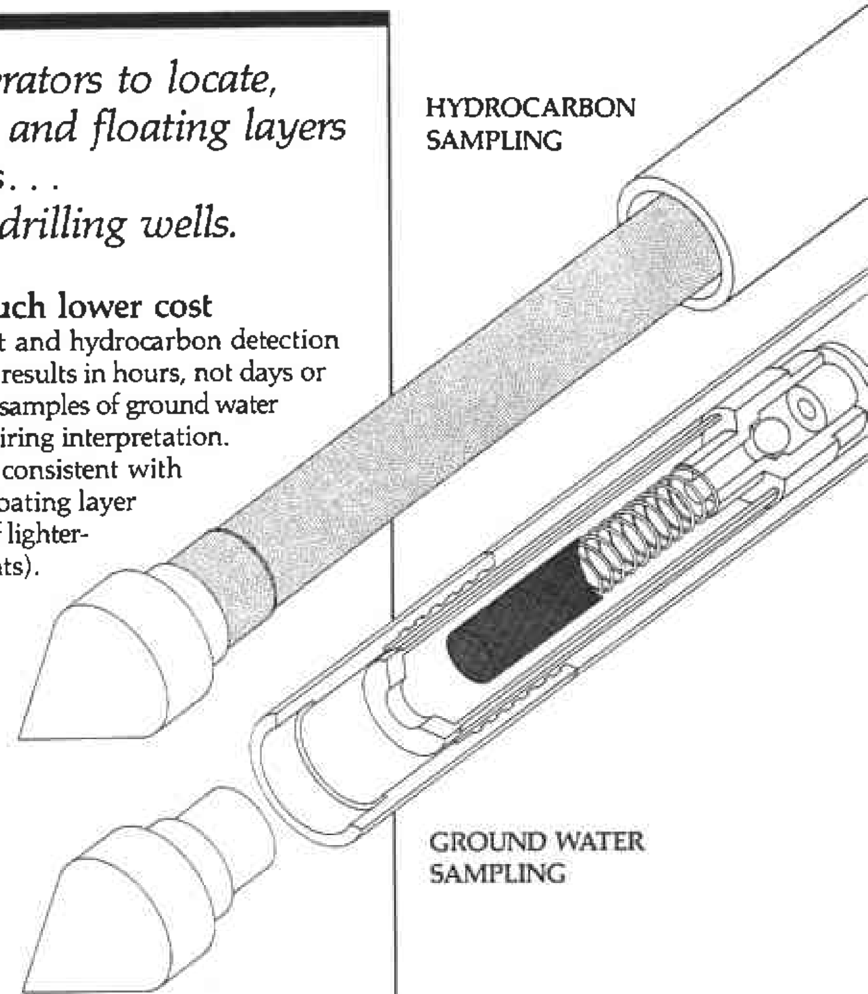
The HydroPunch fills using the aquifer's hydrostatic pressure, similar to the way a bailer fills; thus the formation thickness and yield determine the fill rate. The sample inlet area of the HydroPunch must be in hydraulic contact with a water-bearing zone to collect a sample. Because the sample chamber is above the inlet, the HydroPunch point must be driven to a minimum of 5 ft. below the static water level so that hydrostatic pressure is high enough to assure normal fill times and adequate sample volumes.

Typical application using HydroPunch with cone penetrometer equipment.

HYDROPUNCH®

Floating Layer and Ground Water Sampler

HydroPunch II enables drill rig operators to locate, measure, and sample ground water and floating layers of gasoline and other hydrocarbons . . . rapidly and economically, without drilling wells.



Quality samples in an hour or less—at much lower cost

HydroPunch II is a breakthrough in site assessment and hydrocarbon detection technology. Sampling is so rapid, you can have reliable results in hours, not days or weeks. Unlike indirect survey methods, it delivers actual samples of ground water and floating hydrocarbons—not indirect readings requiring interpretation.

Ground water collected with the HydroPunch II is consistent with monitoring requirements *for all priority pollutants*. Floating layer samples accurately identify and estimate the thickness of lighter-than-water hydrocarbons (i.e. gasoline, fuel oil, solvents).

Better yet, HydroPunch II collects these samples at as little as 1/10 the cost of drilling, casing, and developing conventional monitoring wells. Replaceable screens make field cleaning for multiple grabs fast and easy. There's minimal environmental disturbance—with no permanent installation or well development water.

How the HydroPunch II works

The sampling tool is driven to the desired depth in unconsolidated formations. Preliminary grabs or other information help determine the approximate sampling depth. An auger or split barrel sampler is often used to provide a "pilot hole" to the area just above the sampling zone.

For floating layer applications

After inserting the polypropylene screen and attaching the point, the HydroPunch II is fixed to the casing, lowered through the pilot hole, and driven to the proper depth. The tool is then withdrawn approximately 48", leaving the point in the ground and exposing the screen so that ground water and floating product can enter.

A 1" O.D. Teflon® bailer is lowered through the hollow interiors of the drive casing and body of the HydroPunch II to collect the sample.

For ground water applications

Insert the ball check valves and stainless steel screen, then attach the point. The tool is driven to the proper zone (at least 5 foot submergence for ground water sampling), then withdrawn approximately 18" to expose the inlet screen. The interior fills with water. When the HydroPunch II is recovered, the check balls keep the sample from draining. The point remains in the ground.

Discharge to sample containers is easy with the supplied stopcock. Throughout the process, the sample contacts only stainless steel and Teflon.

Specifications

Dimensions:
Length: 55.5" overall (closed)
O.D.: 2" (nominal)
Weight: 24 lbs. (approximate—varies with configuration)
Sample volume: 1 liter (ground water)
unlimited (floating layer)

Materials:
Body and fittings: 304 stainless steel
Drive shoes: hardened carbon steel (std.)
stainless steel (optional)
Adapters: AW drill rod (ground water)
— carbon steel
EW casing (floating layer)
— carbon steel
Check balls: Teflon® or stainless steel

Screens: 5.25" long 125-micron 120 mesh stainless steel (ground water)
48" long x 1.375" O.D. polypropylene (floating layer)
Replaceable points: lead-free carbon steel

Basic kit:
Body, drive shoes, AW and EW adapters, check ball assemblies, cleaning brush set, 10 replaceable points, 5 stainless steel screens, 5 polypropylene screens, in a protective carrying case

Replaceable supplies:
Points (10/cs)
Stainless steel screens (10/cs)
Polypropylene screens (10/cs.)

QED
Ground Water Specialists
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